ALUMINUM EXTRUDERS WORKING TOGETHER TO IMPROVE PRODUCTS, MARKETS, AND THE INDUSTRY

June 21, 2002

Ms. Brenda Edwards-Jones
U.S. Department of Energy
Office of Building Technologies Program
1000 Independence Avenue, SW
Washington, DC 20588

Dear Ms. Edwards-Jones:

The attached comments reflect the views of the Aluminum Extruders Council, and that of our membership, with regard to the proposed Energy Star program for fenestration products. The Aluminum Extruders Council is the trade association of the leading manufacturers of extruded aluminum profiles in North America and throughout the world. As of January 1, 2002, there are 175 company members of AEC. Among those are 95 extruders that, combined, operate 202 aluminum extrusion plants. We appreciate the opportunity to comment on these critically important issues.

Yours truly,

ALUMINUM EXTRUDERS COUNCIL

Rand A. Baldwin, CAE
President

Enclosures (6)

ALUMINUM EXTRUDERS COUNCIL

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COMMENTS OF THE ALUMINUM EXTRUDERS COUNCIL ON DEPARTMENT OF ENERGY'S ENERGY STAR PROGRAM FOR WINDOWS

The Aluminum Extruders Council (AEC) appreciates the opportunity to provide comments on the Department of Energy's (DOE) proposed criteria for the ENERGY STAR windows program. The AEC is very concerned that the proposal is detrimental to the aluminum window industry and does not take a number of important factors into account. AEC believes that aluminum windows have an important role as an energy efficient product and the ENERGY STAR windows program should not be designed to limit the use of these products. In particular, setting the southern zone U factor at $\leq$ 0.65 eliminates non-thermally broken aluminum products from areas that require this product for disaster resistance. Also, this zone uses the vast majority of its energy on cooling needs as opposed to heating. Further, the proposed central zone is so large that setting a single standard for a 4000 heating degree day (HDD) range involves unacceptable trade-offs. Our comments are divided into several main topics: ENERGY STAR standards relative to International Energy Conservation Code; the ENERGY STAR map accuracy for the southern zone; disaster resistance structural issues; the central zone U factor; durability; and life cycle costs.

AEC also recommends that DOE should not issue final standards until completion of an ongoing study by the National Fenestration Rating Council (NFRC) on durability of window systems. However, if DOE believes it must move ahead with new ENERGY STAR standards before the completion of the NFRC durability study, the AEC endorses Proposal 7 analyzed in "An Evaluation of Alternative Qualifying Criteria for ENERGY STAR Windows: May 8, 2002". Proposal 7 addresses several major AEC concerns and saves more energy than the IECC and the current ENERGY STAR requirements.

1. The Proposed ENERGY STAR Map/Logo Should More Accurately Reflect The Southern Zone To Include All Areas With < 2000 HDD.

The proposed ENERGY STAR standards continue to divide the country into three zones (north, central, and southern), but the heating-degree-day boundaries between the three zones have shifted substantially. Because the southern zone has shrunk dramatically (from areas < 3500 HDD to < 2000 HDD), the new southern zone MUST also show the areas within California and Arizona (as well as a larger area of Texas) that meet this criteria. There is simply no rational basis to exclude these areas that meet this criteria from the map. If these areas meet the criteria set forth, the map must include them. The alleged basis for alteration of the map is that DOE would like to keep zones continuous for consumer simplicity, but map alterations to address AEC's concern would still create a label that allows consumers to easily identify the most energy efficient subset of the market. Indeed, manufacturers whose products meet the central zone requirements would also qualify for an ENERGY STAR rating in the southern zone. This adjustment in the map/graphic is made all the more important by the greatly diminished area of the country in which aluminum products can qualify for an ENERGY STAR label. DOE's analysis of the proposal asserts that it is concerned about continued use of aluminum; however, the proposed standards and map appear to belie that concern.

2. Hurricane-Related Structural Integrity Should Be Considered In Establishing Standards For The Southern Region As Well As Other Areas That Are Prone To Hurricane Impact.

The IECC standard and the October 2001 proposed ENERGY STAR standard set a U factor for the southern zone at $\leq$ 0.75. Part of the rationale for the chosen U factor in the southern zone was to keep non-thermally broken aluminum windows as an option to meet structural integrity standards (disaster resistance) for hurricane codes. This would allow aluminum-framed windows to continue to achieve an ENERGY STAR rating in the southern zone. The current ENERGY STAR proposal would set the U factor at $\leq$ 0.65. This eliminates virtually all operable, non-thermally broken windows. In addition, few fixed, non-thermally broken windows can meet the standard. Thus, as a practical matter, few windows in these areas will both meet hurricane codes and achieve an ENERGY STAR rating.

DOE gives little, if any, explanation for the change from a U factor of 0.75 to 0.65 and appears to disregard one of the most significant benefits of aluminum window systems -- structural integrity for hurricanes, tropical storms and other high wind/rain conditions. In the southern region, cooling loads almost totally dominate energy use, so an emphasis on SHGC is very appropriate. The energy saved by dropping the U factor from 0.75 to 0.65 is minimal (less than 6% of total energy savings – calculated from the

October 2001 and May 2002 proposals) and more than offset by disaster resistance and product availability issues.

Further, disaster-resistance (specifically hurricanes/tropical storms) issues extend into areas beyond the southern zone. This is important in North Carolina, South Carolina, Virginia, and even some coastal areas further north. In the last ten years, eight hurricanes have struck in areas outside the southern zone (see Attachment 1). For example, Charleston, South Carolina and Raleigh-Durham, North Carolina have suffered major damage from hurricanes. Attachment 2 shows the storm wind speeds and required building codes encountered on the East and Gulf Coasts. As a result, numerous regions in this area have adopted (or are considering adopting) structural standards for windows that rely on aluminum frames. At a minimum, DOE must include a note on its map to indicate that the southern zone requirements are the appropriate energy efficiency standards for hurricane prone areas in the mid-Atlantic / southeastern states that have adopted disaster-resistance, structural integrity codes. To fail to do so would do a major disservice to citizens who live in these areas who want both structural integrity and energy savings.

3. The Central Zone U Factor Must Be Changed -- A Four-Tier System Should Be Adopted.

The proposed central zone covers too large a region (2000 to 6000 HDD) and, therefore, results in too many compromises in establishing ENERGY STAR requirements.

Requiring an energy efficient window in Las Vegas to meet the same insulating standards as an energy efficient window in New York City simply doesn't make sense.

The proposed 0.40 U factor requirement for the central zone effectively eliminates aluminum window products (thermally broken) from achieving an ENERGY STAR rating. Offering consumers as many product choices as possible ensures competition and helps keep costs low; thus, thermally broken aluminum windows should remain in the mix of products that can qualify for an ENERGY STAR in this zone.

In order to more rationally design the new program, ENERGY STAR should adopt a four-tier system with 2000 – 3499 HDD as a south-central zone. Since most of the areas with 2000-3499 HDD are concerned about cooling, as opposed to heating, the key factor DOE should consider is SHGC. The U factor is much less important with respect to cooling. Therefore, DOE should establish a U factor for this zone that provides structural integrity for windstorms that hit these areas on a more-or-less routine basis. Aluminum windows with a U factor of 0.65 combined with the SHGC of ≤ 0.4 will provide the optimum in cooling while meeting structural needs of consumers in these areas. AEC recognizes the IECC code for these areas is 0.5. If DOE is compelled to look beyond cooling and structural issues, there is no reason to go beyond the level set in the IECC code.

A four-tier map would still provide an easy to interpret logo/graphic for consumers. Many manufacturers will only market a product as ENERGY STAR if it meets requirements in every region, so subdividing the central region will not have a large impact on the market. Even for those manufacturers that label products on a regional basis, a four-tier map would not impose any significant additional burden. As to confusion to consumers, a four-tier map provides <u>better</u> information to consumers, since they can more realistically determine products that are appropriate to their region.

DOE has acknowledged in the analysis of the proposed standards that the number of thermally broken aluminum framed windows that can meet a U factor ≤ 0.4 are very limited and would be more expensive. Cost information from our members indicates that decreasing the U factor of a thermally broken aluminum frame window that meets a 0.5 standard to the proposed ≤ 0.4 adds at least 20 to 25% to the cost of the window. This cost increase would effectively remove efficient aluminum windows from the market. DOE has already stated that cost issues are important in establishing the requirements. For example, lower U factors could be achieved for the northern zone, but this would generally require triple glazing at a premium of 30-50%. DOE determined that this cost was too high to justify a lower U factor. The same logic must be applied when determining the tiers for the central regions.

Product availability and price issues are very important to consumers. With an adjustment of the U factor in the south central region, consumers will be able to choose among wood, vinyl, and aluminum ENERGY STAR rated products. Other countries have determined that it is important to keep aluminum products viable for other reasons (particularly environmental, life cycle energy, and durability/structural). For example, Great Britain allows for slightly different U factors between aluminum and vinyl. Their requirements are 0.38 for aluminum and 0.35 for vinyl modeled at a boundary condition of 0 degrees F. Europe uses slightly different modeling, but if the U.S. modeled in the same way, the resulting U factors would be 0.41 for aluminum and 0.38 for vinyl (see Attachment 3). The United States should adopt a policy that keeps consumer choice while meeting energy conservation objectives. By adopting the four-tier system, all objectives would be met.

4. Durability Should Be Considered In Establishing Standards For All Regions.

Because DOE assumes a 40-year life for windows, how well a window maintains its energy saving properties (U factor and SHGC) over time is very important. Vinyl windows may be able to meet lower initial U factors than thermally broken aluminum windows in certain circumstances, but they are not as durable as aluminum windows over the long term. As a result of deformation, vinyl windows will have unacceptable rates of air leakage and a much lower effective U factor than aluminum windows. This fact is supported by a 1994 study, "Durability Evaluation of Aluminum and PVC Windows Subjected to Pressure and Temperature Cycling" (Attachment 4) which found that vinyl windows suffer deformation over time. As one might expect, in all the windows tested air-tightness performance degraded as cycling progressed, but aluminum windows were superior to vinyl, particularly as the testing progressed. Although one of the aluminum windows tested experienced a crack in a structural member (the type of manufacture used for this window is no longer in practice), aluminum windows performed very well particularly compared with vinyl. At the end of the test, all the aluminum windows met the minimum performance requirements for ease of operation and air tightness (specified in CAN/CSA A440-M90) while the vinyl windows did not. This air leakage/loss of insulating ability will offset any benefit gained through the lower initial U factor and undermine energy savings assumptions (especially considering 40-year window life) used by DOE in establishing ENERGY STAR performance standards. As this study shows, DOE must consider durability in establishing ENERGY STAR standards. However, AEC can find nothing in the record to show that this factor has been considered in any way. It appears that only initial U factors are considered.

NFRC is currently conducting the "Environmental and Ergonomic Exposure Testing Program". This program addresses the performance criteria of air leakage, durability, and operating/breakaway force (Attachment 5). A total of 24 windows, made of wood, vinyl, and aluminum are being tested. Final thermal tests will be conducted on sealed and unsealed windows to determine the impact of air infiltration on U factor. The test is scheduled to be completed by October 2002. AEC recommends DOE delay any implementation of new ENERGY STAR standards until the results of this testing program are known so they may be used in determining ENERGY STAR requirements.

5. DOE Should Consider Other Life-Cycle Costs In Determining ENERGY STAR Requirements.

In addition to the energy saved during its use, windows also consume energy during their manufacture and ultimate disposal. AEC suggests that DOE consider full life-cycle costs as part of its window-rating criteria. Aluminum windows offer lower life cycle costs than vinyl products, as well as easier (and valuable) recycling. Less than 1% of vinyl is recycled in the United States. Disposal of vinyl creates significant environmental problems (e.g., releases of toxic materials into the air or water), whereas more than 65% of aluminum is recycled in the U.S. Recycling aluminum for new products uses less than 5% of the energy required when making aluminum from raw materials. This creates tremendous energy and environmental benefits that should be factored into DOE's analysis. In addition, aluminum windows offer superior fire resistance as well as superior performance in the event of the fire, particularly in the area of toxic gas release. These factors apparently have not been considered by DOE in developing this proposal. DOE should consider methods to evaluate these factors in setting ENERGY STAR requirements.

6. It Is Not Necessary For ENERGY STAR Standards To Exceed IECC On Principle.

AEC understands that ENERGY STAR was created to provide a "market pull" for more efficient products. Although many states have adopted building codes with requirements for energy efficient windows, these are almost always focused on new construction. Given that replacement windows make up slightly more than half the windows' market, ENERGY STAR can provide an incentive to fill an important gap in energy savings. In setting new standards for ENERGY STAR, the DOE must consider how far those standards should push efficiency beyond that of existing sales or the International Energy Conservation Code (IECC), as well as the consequences of any such standards. In many other ENERGY STAR product lines, there is no energy code-setting body such as the IECC. We do not believe it is necessary for ENERGY STAR requirements to exceed those of the IECC as a matter of philosophy. Because not all states will adopt IECC and because most states only use this code for new construction, even if ENERGY STAR standards are set at IECC standards, this will create an opportunity for substantial market pull of window products classified as efficient by the IECC. ENERGY STAR's primary mission – to expand the market for energy efficient products – will still be fulfilled, energy will be saved and other important factors associated with the building industry will be addressed.

CONCLUSION

For the reasons stated above, DOE should consider a wider set of factors in establishing ENERGY STAR standards for windows. DOE should modify the map to make it more accurately reflect the heating and cooling needs in different regions of the United States. AEC is ready to work with DOE as it undertakes this effort.

Attachments

1. Hurricane information fact sheet

2. Map with areas adopting disaster resistance structural codes and storm wind speeds

3. Building Regulation Document L (Great Britain) for dwellings

4. Durability Evaluation of Aluminum and PVC Windows (complete report text).

5. Testing Criteria for NFRC's Environmental and Ergonomic Testing Program.

Hurricane Information Fact Sheet

Direct Hurricane hits on individual states form 1900-1996

State	Total Number of Hurricane Direct Strikes
Maryland	1
North Carolina	25
South Carolina	14
Virginia	4

Source: NCEP home page

Hurricanes that have struck in Maryland, North Carolina, South Carolina, and Virginia from 1989-2000 (direct strike and damage)

Maryland

Name of Hurricane	Year
Bertha	1998
Floyd	1999

North Carolina

Name of Hurricane	Year
Emily	1993
Felix	1995
Bertha	1996
Fran	1996
Bonnie	1998
Floyd	1999

South Carolina

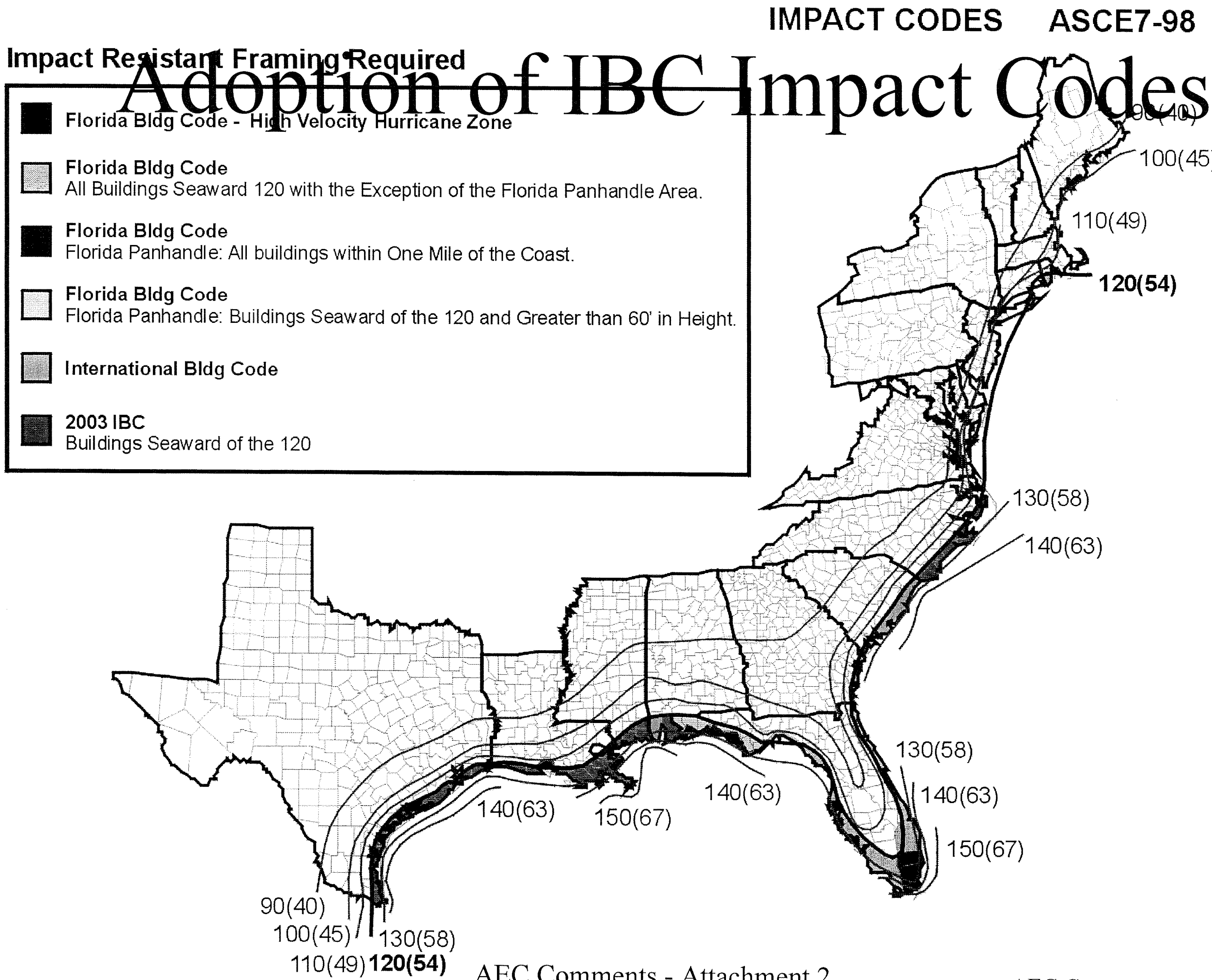
Name of Hurricane	Year
Hugo	1989
Bertha	1996
Fran	1996
Floyd	1999

Virginia

Name of Hurricane	Year
Bertha	1996
Fran	1996
Danny	1997
Bonnie	1998
Floyd	1999

Sources: Washington Post.com, *Power of Hurricanes Report;* FEMA, *Top 10 hurricanes; SC climate office publication;* National Weather Service, Public Information statement, *Virginia Hurricanes Past, Present and Future;* UNISYS, *Hurricane data from 1995-2000*; A History of Hurricanes in North Carolina homepage

Adoption of IBC Impact Codes



AEC Comments - Attachment 2

Section 1: Design and Construction

Alternative methods of showing compliance

1.1 Three methods are shown for demonstrating reasonable provision for limiting heat loss through the building fabric:

a) An Elemental method;

b) A Target U-value method;

c) A Carbon Index method.

1.2 The Elemental Method can be used only when the heating system will be based on an efficient gas or oil boiler, on a heat pump, on community heating with CHP or on biogas or biomass fuel, but not for direct electric heating or other systems. The Target U-value Method and the Carbon Index Method can be used with any heating system.

Elemental method

U-values for construction elements

1.3 The Elemental Method is suitable for alterations and extension work, and for new-build work when it is desired to minimise calculations. When using the Elemental Method, the requirement will be met for new dwellings by selecting construction elements that provide the U-value thermal performances given in Table 1.

1.4 One way of achieving the U-values in Table 1 is by providing insulation of an appropriate thickness estimated from the tables in Appendix A. An alternative for walls and roofs is to use the combined method of calculation outlined in Appendix B and set out in more detail in the CIBSE Guide Section A3 1999 Edition. An alternative for floors is to use the data given in Appendix C. An alternative for basements is given in the BCA/NHBC Approved Document "Basements for dwellings"[3].

1.5 Door designs can include various panel arrangements but the indicative U-values given in Appendix A, Table A1 will generally be acceptable. Single-glazed panels can be acceptable in external doors provided that the heat loss through all the windows, doors and rooflights does not exceed that of the standard provision given in paragraphs 1.8 to 1.10 below.

1.6 Care should be taken in the selection and installation of appropriate sealed double-glazed windows in order to avoid the risk of condensation forming between the panes. Guidance on avoiding this problem is given in BRE Report No 262 "Thermal insulation: avoiding risks", 2002 edition.

Heating efficiency

1.7 Reasonable provision for boiler efficiency would be demonstrated by using a boiler with SEDBUK[4] not less than the appropriate entry in Table 2.

Table 1 Elemental Method: U-values (W/m^2K) for construction elements

Exposed Element	U-value
Pitched roof with insulation between rafters[1]	0.2
Pitched roof with integral insulation	0.25
Pitched roof with insulation between joists	0.16
Flat roof[3]	0.25
Walls, including basement walls	0.35
Floors, including ground floors and basement floors	0.25
Windows, doors and rooflights[4] (area weighted average), glazing in metal frames[5]	2.2
Windows, doors and rooflights[4] (area-weighted average), glazing in wood or PVC frames[4]	2.0

Notes to Table 1:
[1] Any part of a roof having a pitch of 70° or more can be considered as a wall.
[2] For the sloping parts of a room-in-the-roof constructed as a material alteration, a U-value of 0.3 W/m^2K would be reasonable.
[3] Roof of pitch not exceeding 10°.
[4] Rooflights include roof windows.
[5] The higher U-value for metal framed windows allows for additional solar gain due to the greater glazed proportion.

Table 2 Minimum boiler SEDBUK to enable adoption of the U-values in Table 1, and reference boiler SEDBUK for use in the Target U-value Method

Central heating system fuel	SEDBUK[1] %
Mains natural gas	78
LPG	80
Oil	80[2]

Notes to Table 2
[1] For boilers for which the SEDBUK is not available, the appropriate seasonal efficiency value from Table 4b of the SAP may be used instead (see paragraphs 0.17-0.18).
[2] For oil-fired combination boilers a SEDBUK of 82%, as calculated by the SAP-98 method, would be acceptable.

Areas for windows, doors and rooflights

Standard Area Provision

1.8 The requirement would be met if the average U-value of windows, doors and rooflights matches the relevant figure in Table 1 and the area of the windows, doors and rooflights together does not exceed 25% of the total floor area.

1.9 The average U-value is an area-weighted average for the whole dwelling, and depends on the individual U-values of the glazed components and door components proposed and their proportions of the total area of openings. Examples of how the average U-value is calculated are given in Appendix D.

Adapting the Standard Area Provision for particular cases

1.10 Areas of windows, doors and rooflights larger than that given in paragraph 1.8 may be adopted in particular cases by using the Target U-value Method to demonstrate compliance. Another option would be to reduce the area of windows, doors and rooflights to compensate for a higher average U-value (ie lower performance glazing). However reducing glazing area could lead to inadequate daylighting.

Extensions to dwellings

1.11 The fabric U-values given in Table 1 in the Elemental Method can be applied when proposing extensions to dwellings. The Target U-value and Carbon Index Methods can be used only if applied to the whole enlarged dwelling.

1.12 Only when applied to extension works, the U-values in Table 1 may be varied provided that the total rate of heat loss from the extension is no higher than it would be if all elements had the U-values given in Table 1. The total rate of heat loss is the sum of (area x U-value) for all exposed elements. As an example, where the floor area and the roof area are equal, it would be acceptable for the roof to have a U-value of 0.18 W/m^2K if the floor U-value is 0.23 W/m^2K.

1.13 For small extensions to dwellings (for example, ground-floor extension to single rooms such as kitchen extensions in terraced houses, porches where the new heated space created has a floor area of not more than about 6 m^2), reasonable provision would be to use construction details that are no worse in energy performance terms than those in the existing building.

1.14 The area-weighted average U-value of windows, doors and rooflights ("openings") in extensions to existing dwellings should not exceed the relevant values in Table 1. An appropriate area provision for openings for extensions could be established where:

a) the area of openings in the extension does not exceed 25% of the floor area of the extension plus the area of any windows or doors in the existing dwelling which, as a result of the extension works, no longer exist or are no longer exposed; or

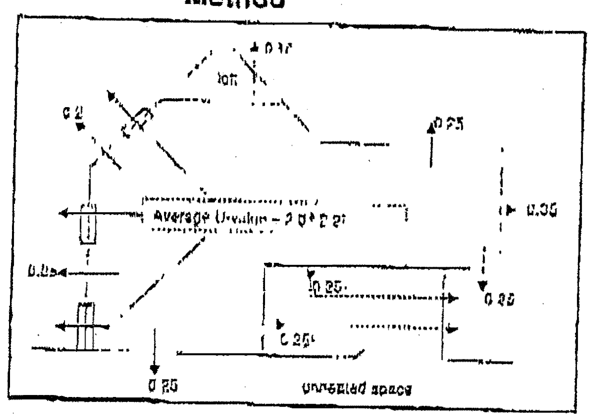
b) the area of openings in the enlarged dwelling does not exceed the area of openings in the existing dwelling; or

c) the area of openings in the enlarged dwelling does not exceed 25% of the total floor area of the enlarged dwelling.

Summary of provisions in the elemental method

1.15 Diagram 1 summarises the fabric insulation standards and allowances for windows, doors and rooflights given in the Elemental method. Examples of the procedures used in this method are given in Appendices A to C. For the calculation of U-values of elements adjacent to an unheated space, see paragraph 0.8 in Section 0.

Diagram 1 Summary of Elemental Method



* If windows have wood or PVC frames
† If windows have metal frames
Includes the effect of the unheated space (see paragraph 0.8)

Target U-value method for new dwellings

1.16 Within certain limits, this method allows greater flexibility than the Elemental Method in selecting the areas of windows, doors and rooflights, and the insulation levels of individual

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[21] Approved Document - Basements for dwellings, BCA/NHBC, 1997, ISBN 0 7210-1508-6

[22] SEDBUK is the Seasonal Efficiency of a Domestic Boiler in the UK, defined in The Government's Standard Assessment Procedure for the Energy Rating of Dwellings (see paragraphs 0.17-0.18)

Section 2: Work on existing dwellings

Replacement of controlled services or fittings

2.1 "Controlled Service or fitting" is defined in Regulation 2(1) of the Building Regulations 2000 (as amended by the Building (Amendment) Regulations 2001) as *"a service or fitting in relation to which Part G, H, J or L of Schedule 1 imposes a requirement;"*.

2.2 The definition of building work in Regulation 3(1) includes the provision or extension of a controlled service or fitting in or in connection with a building. This is qualified in Regulation 3(1A) as follows:

"The provision or extension of a controlled service or fitting –

(a) in or in connection with an existing dwelling; and

(b) being a service or fitting in relation to which paragraph L1, but not Part G, H or J, of Schedule 1 imposes a requirement,

shall only be building work where that work consists of the provision of a window, rooflight, roof window, door (being a door which together with its frame has more than 50 per cent of its internal face area glazed), a space heating or hot water service boiler, or a hot water vessel."

2.3 Reasonable provision where undertaking replacement work on controlled services or fittings (whether replacing with new but identical equipment or with different equipment and whether the work is solely in connection with controlled services or includes work on them) depends on the circumstances in the particular case and would also need to take account of historic value (see paragraph 2.9 *et seq*). Possible ways of satisfying the requirements include the following:-

a) **Windows, doors and rooflights.** Where these elements are to be replaced, providing new draught-proofed ones either with an average U-value not exceeding the appropriate entry in Table 1, or with a centre-pane U-value not exceeding 1.2 W/m²K (the requirement does not apply to repair work on parts of these elements, such as replacing broken glass or sealed double-glazing units or replacing rotten framing members). The replacement work should comply with the requirements of Parts L and N. In addition the building should not have a worse level of compliance, after the work, with other applicable Parts of Schedule 1. These may include Parts B, F and J.

b) **Heating boilers.** Where heating boilers are to be replaced in dwellings having a floor area greater than 50m². providing a new boiler as if for a new dwelling i.e:-

(1) in the case of ordinary oil or gas boilers, providing a boiler with a SEDBUK not less than the appropriate entry in Table 2[32], together with appropriate controls following the guidance starting at paragraph 1.36. (In the case of replacement boilers installed in the period up to 31 August 2002, it would be reasonable to provide a less efficient boiler provided the heating controls comply with specification HR2 or HC2 given in GIL 59[33];

(2) in the case of back boilers, providing a boiler having a SEDBUK of not less than three percentage points lower than the appropriate entry in Table 2;

(3) in the case of solid fuel boilers, providing a boiler having an efficiency not less than that recommended for its type in the HETAS certification scheme.

c) **Hot water vessels.** When replacing hot water vessels, reasonable provision would be to provide new equipment as if for a new dwelling following the guidance beginning at paragraph 1.43.

d) **Boiler and hot water storage controls.** So that replacement boilers (other than solid fuel boilers) and hot water vessels can achieve reasonable seasonal efficiency, the work may also need to include replacement of the time switch or programmer, room thermostat, and hot water vessel thermostat, and provision of a boiler interlock and fully pumped circulation. Section 3 of GPG 302[34] gives more advice on how this can be done.

e) As an alternative to a) to d), following the guidance in, for example, GPG 155[35] may be acceptable provided that an equivalent improvement in the dwelling's Carbon Index is achieved.

f) **Commissioning and providing operating and maintenance instructions.** Where heating and hot water systems are to be altered as in paragraphs (a) to (e), reasonable provision would also include appropriate commissioning and the provision of operating and maintenance instructions following the guidance in paragraphs 1.47 to 1.51.

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[32] For boilers for which the SEDBUK is not available, the appropriate seasonal efficiency value from Table 4b of the SAP may be used instead (see paragraphs 0.17-0.18).

[33] GIL 59 2000: Central Heating system specifications (CheSS)

[34] GPG 302, 2001, Controls for domestic central heating and hot water. BRECSU.

[35] GPG 155, 2001: Energy efficient refurbishment of existing housing. BRECSU

Durability Evaluation of
ALUMINUM AND PVC WINDOWS
Subjected to Pressure and Temperature Cycling

Report No. L94-15001-2
October 11, 1994

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Durability Evaluation of
ALUMINUM AND PVC WINDOWS
Subjected to Pressure and Temperature Cycling

ABSTRACT

This report presents the results of durability evaluation of aluminum and PVC windows subjected to cycling of pressure and exterior ambient and surface temperatures. Three window types of each material (total six windows) were considered for this evaluation: a vertical slider, a horizontal slider and a casement. The test windows were selected and acquired by CAN-BEST from major Canadian Manufacturers based on common availability and demonstrated compliance with CAN/CSA A440-M90 window standard.

The evaluation procedure comprised of monitoring the rate of air leakage through the test windows while being subjected to cycling of pressure and temperature for a period of 29 days. During cycling, comparative air leakage measurements were carried out on all windows at 75 Pa (1.57 psf) pressure differential. In addition, the overall effect of cycling on window performance with respect to its ease of operation and air tightness was determined by testing in accordance with CAN/CSA A440-M90 prior to and following cycling.

Pressure and Temperature Cycling
The test samples were subjected to superimposed cycling of pressure, and ambient and surface temperatures for a period of 29 days.

Pressure Cycling - Pressure cycling was carried out between 0 and -1.5 kPa (0 to -31 psf), equivalent to C1 rating, continuously at the rate of one cycle per minute (an average of 1,440 cycles per day) for the entire duration of temperature cycling.

Temperature Cycling - Temperature cycling was performed in general accordance with ASTM's draft procedure prepared by subcommittee E06051 *"Standard Practice to Determine the Effects of Temperature Cycling Plus Infrared Radiation on Fenestration Systems, Draft #15, March 22, 1993"*. The procedure was modified to accommodate the superimposed pressure cycling, whereby the specified exterior ambient low temperature of -30°C was raised to -26° during cycling due to the increased cooling load imposed by the simultaneous pressure cycling of windows.

Ambient temperature cycling, between -26°C and 50°C (-15°F and 122°F) was carried out at the rate of four cycles per day for 29 days. Surface temperature cycling between 21°C and 70°C (70°F and 158°F) measured on a black surface was carried out, in phase with ambient temperature cycling, at the rate of four cycles per day.

Test Results
Aluminum Windows:
The aluminum windows exhibited general progressive increase in air leakage rate during cycling. Following 29 days of cycling, the windows met the minimum performance level requirements for ease of operation and air tightness specified in CAN/CSA A440-M90 window standard.

PVC Windows:
The increase in air leakage rate proceeded at a higher rate than that of the aluminum windows. Following 29 days of cycling, the PVC windows met the ease of operation performance requirement. However, the windows failed to meet the minimum air tightness performance level requirement of CAN/CSA A440-M90. The air tightness rating fell below A1 on the 19th day of cycling for both the vertical and horizontal sliders and on the 27th day for the casement.

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1. INTRODUCTION

Canadian Building Envelope Science and Technology (CAN-BEST) was retained by the Aluminum Extruders Council (AEC) to evaluate the durability of aluminum and PVC windows subjected, simultaneously, to cycling of pressure and exterior ambient and surface temperatures. Three window types of each material (total six windows) were considered for this evaluation: a vertical slider, a horizontal slider and a casement.

The evaluation procedure comprised of monitoring the rate of air leakage through the test windows prior to, during and following cycling of pressure and temperature. The ease of operation and air tightness of the test windows were evaluated prior to and following cycling in accordance with CAN/CSA A440-M90 window standard.

This report covers tests carried out on one specimen of each window type and material prior to and following a specific conditioning process. Window performance is affected by variations in dimensions, assembly details and installation method. Therefore, the reported test results refer only to the specimen tested. No representation is made that other samples of similar design will feature like performance.

2. SELECTION OF TEST WINDOWS

The test samples were selected and acquired by CAN-BEST from major Canadian Manufacturers based on common availability and demonstrated compliance with CAN/CSA A440-M90 window standard. All the test windows were white in colour, and having dimensions in accordance with CAN/CSA A440-M90 window standard as follows:

- *Vertical Slider, 1000 mm wide x 1600 mm high (39.4" x 63.0")*
- *Horizontal Slider, 1600 mm wide x 1000 mm high (63.0" x 39.4")*
- *Casement, 700 mm wide x 1600 mm high (27.5" x 63.0")*

3. DESCRIPTION OF TEST WINDOWS

Table (1) presents a summary description of the test samples. Detailed description of each test sample is found in Appendix (A).

TABLE (1): DESCRIPTION OF TEST SAMPLES

Window Type	Window Description	Glazing
Aluminum Vertical Slider	1000 mm wide x 1600 mm high Thermally broken aluminum (frame and sash), vertically sliding, double hung window consisting of two inward-tilting and sliding sash panels, each supported with one pair of sash balances.	Single run double-glazed sealed insulating unit
Aluminum Horizontal Slider	1600 mm wide x 1000 mm high Thermally broken aluminum frame, horizontally sliding, double run window consisting of two inner and two outer sliding sash panels	Double run, single-glazed sash panels
Aluminum Casement	700 mm wide x 1600 mm high Thermally broken aluminum (frame and sash), outward-projecting casement window	Double-glazed sealed insulating unit
PVC Vertical Slider	1000 mm wide x 1600 mm high Non-reinforced PVC, thermally welded mitred corners (frame and sash), double hung window consisting of two inward-tilting and vertically sliding sash panels, each supported with one pair of sash balances	Single run double-glazed sealed insulating unit
PVC Horizontal Slider	1600 mm wide x 1000 mm high Non-reinforced PVC, thermally welded mitred corners (frame and sash), window consisting of two inward-tilting and horizontally sliding sash panels	Single run double-glazed sealed insulating unit
PVC Casement	700 mm wide x 1600 mm high Non-reinforced PVC, thermally welded mitred corners (frame and sash), outward-projecting casement window	Double-glazed sealed insulating unit

4. EVALUATION PROCEDURE

The evaluation procedure comprised of monitoring the rate of air leakage through the test windows while being subjected to cycling of pressure and temperature for a period of 29 days. During cycling, comparative air leakage measurements were carried out at 75 Pa (1.57 psf) pressure differential, in general accordance with ASTM E283-91, with the exception of the environmental and sample temperature conditions. The air leakage measurements were performed during the changeover of the exterior ambient temperature from high to low, and while it was within 5° of the interior ambient temperature.

4.1 INITIAL AND FINAL EVALUATION

The overall effect of pressure and temperature cycling on window performance with respect to its ease of operation and air tightness was determined by testing in accordance with CAN/CSA A440-M90 prior to and following cycling. The initial and final air tightness tests were carried out in accordance with ASTM E283-91 under standard laboratory temperature condition.

4.2 PRESSURE AND TEMPERATURE CYCLING

The test samples were subjected to superimposed cycling of pressure and exterior ambient and surface temperatures for a period of 29 days.

Pressure Cycling:
Pressure cycling was carried out between 0 and -1.5 kPa (0 to -31 psf), equivalent to C1 rating. Pressure cycling was carried out continuously at the rate of one cycle per minute (an average of 1,440 cycles per day) for the entire duration of temperature cycling with the exception of 30 minute interruption during air leakage testing.

Pressure cycling was carried out in the outward direction for two reasons, one technical and one practical. Pressure cycling in the outward direction presents a more severe loading condition than that of the inward direction whereby the casement locks and hinges are subjected to direct loading. Also, it is was more practical to maintain a constant inside ambient temperature during cycling by pressurizing the interior test chambre rather than the exterior one.

As shown in Figure (1), a typical 60-second pressure cycle is composed of four stages with durations as follows:
Stage 1. *20-second pressure application stage, 0 to -1.5 kPa*
Stage 2. *10-second pressure maintenance stage, -1.5 kPa*
Stage 3. *10-second pressure release stage, -1.5 kPa to 0*
Stage 4. *20-second window recovery stage, no pressure*

Temperature Cycling:
Temperature cycling was performed in general accordance with ASTM's draft procedure prepared by subcommittee E06051 "*Standard Practice to Determine the Effects of Temperature Cycling Plus Infrared Radiation on Fenestration Systems, Draft #15, March 22, 1993*". The procedure was modified to accommodate the superimposed pressure cycling, whereby the specified exterior ambient low temperature of -30°C was raised to -26° during cycling due to the increased cooling load imposed by the simultaneous pressure cycling of windows.

Ambient temperature cycling between -26°C and 50°C (-15°F and 122°F) was carried out at the rate of four cycles per day. Surface temperature cycling was carried out, in phase with the ambient temperature cycling, between 21°C (70°F) and 70°C (158°F) measured on a black surface.

As shown in Figure (2), a typical six-hour exterior temperature cycle is composed of six one-hour stages with durations as follows:

Stage 1. *ambient cooling stage, room temperature to -26°C*
Stage 2. *ambient low temperature maintenance stage, -26°C*
Stage 3. *ambient warm up stage, -26°C to room temperature*
Stage 4. *heating stage, room temperature to +50°C ambient and +70°C black surface*
Stage 5. *high temperature maintenance stage, +50°C ambient and +70°C black surface*
Stage 6. *cool down stage, +50°C ambient and +70°C black surface to room temperature*

5. TEST RESULTS AND OBSERVATIONS

Figures (3) and (4) show the decline in airtightness performance with cycling time for the aluminum and PVC windows respectively. As indicated by the three curves representing the three window types, the airtightness performance degrades as cycling progressed. This increase in air leakage is attributed mainly to permanent lineal shrinkage of the exposed weatherstrips and other PVC airseal components.

5.1 ALUMINUM WINDOWS

The decline in the airtightness performance of the aluminum windows followed a predictable trend since there was no observed structural failure. However, the casement exhibited an unpredictable increase in air leakage rate towards the end of cycling. This was caused by a longitudinal web crack developed in the slide-in, hollow extruded PVC sash thermal break.

5.1.1 Vertical and Horizontal Sliders

Tables (2) and (3) present the initial and final results of testing for ease of operation and air tightness tests along with the visual observations obtained for the vertical and horizontal sliders respectively. Following 29 days of cycling, the test windows maintained a clean visual appearance, proper function, and good performance. Furthermore, the windows met the performance requirements for ease of operation. However, certain exposed pile weatherstrips and PVC components exhibited substantial lineal shrinkage, which in turn, caused a corresponding drop in the air tightness rating of both windows from A2 to A1.

5.1.2 Casement

Table (4) presents the initial and final results of testing for ease of operation and air tightness tests along with the visual observations obtained for the test sample. Following cycling, the test window maintained a clean visual appearance, proper function, and good performance. Furthermore, the windows met the performance requirements for ease of operation. However, on the 27th day of cycling, the slide-in hollow extruded PVC sash thermal break developed a crack along the top and bottom corners of the hinge-side stile, propagating to approximately 100 mm in length at the end of cycling period (29 days).

The development of the thermal break crack is attributed to a fatigue failure in resisting cyclic and tensile stresses developed by a combination of the following:

- *shear stresses developed by the bending action of the composite stile*
- *direct tensile stresses caused by the outward pull forces exerted by the exterior sash section on the interior section during pressure application.*

In a dry-dry glazing system, the applied outward pressure is transferred from the sash to the frame via the thermal break and the sash' points of attachment to the frame (primarily the hinges and locks). Since the hardware is fastened to the interior sections of the sash members, the total lateral load generated by the applied pressure is transferred from the sash to the frame through the intermediary thermal break, with the highest load concentration found near the hardware components, specifically the hinges which are located at the extreme ends of the stile.

In addition to thermal break failure, certain exposed pile weatherstrips and PVC components exhibited substantial lineal shrinkage, which in turn, caused a corresponding drop in the window's air tightness rating from A3 to A1.

5.2 PVC WINDOWS

The decline in airtightness performance of the PVC windows proceeded at a higher rate than that of the aluminum windows. The airtightness rating fell below A1 on the 19th day of cycling for both the vertical and horizontal sliders, and on the 27th day for the casement.

Tables (5), (6) and (7) present the initial and final results of testing for ease of operation and air tightness tests along with the visual observations obtained for the vertical slider, horizontal slider and casement respectively. Following 29 days of cycling, all windows maintained a clean visual appearance and proper function. Furthermore, the windows met the performance requirements for ease of operation. However certain exposed pile weatherstrips and PVC components exhibited substantial lineal shrinkage, which in turn, caused a failure of all the windows to meet the minimum air tightness requirement specified in CAN/CSA-A440.

6. CONCLUSIONS

Aluminum Windows:

The test windows exhibited general progressive increase in air leakage rate during cycling. Following 29 days of cycling, the windows met the minimum performance level requirements for ease of operation and air tightness specified in CAN/CSA A440-M90 window standard.

PVC Windows:

The increase in air leakage rate proceeded at a higher rate than that of the aluminum windows. Following 29 days of cycling, the windows met the ease of operation performance requirement. However, the windows failed to meet the minimum air tightness performance level requirement of CAN/CSA A440-M90 window standard. The air tightness rating fell below A1 on the 19th day of cycling for both the vertical and horizontal sliders, and on the 27th day for the casement.

Respectfully submitted,

CANADIAN BUILDING ENVELOPE
Science and Technology

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ea/dm/aec8-2.rpt

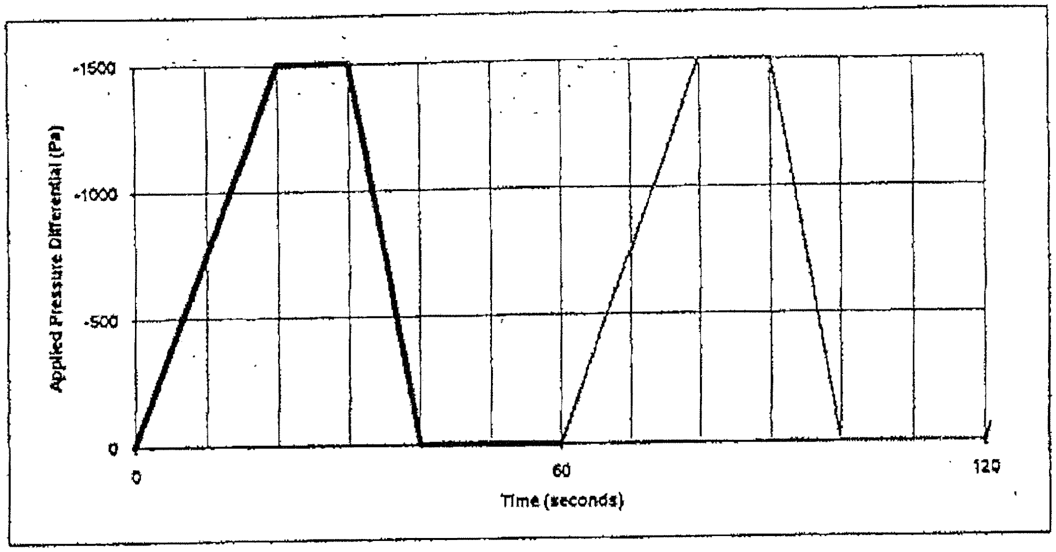


Figure (1): Typical Pressure Cycle

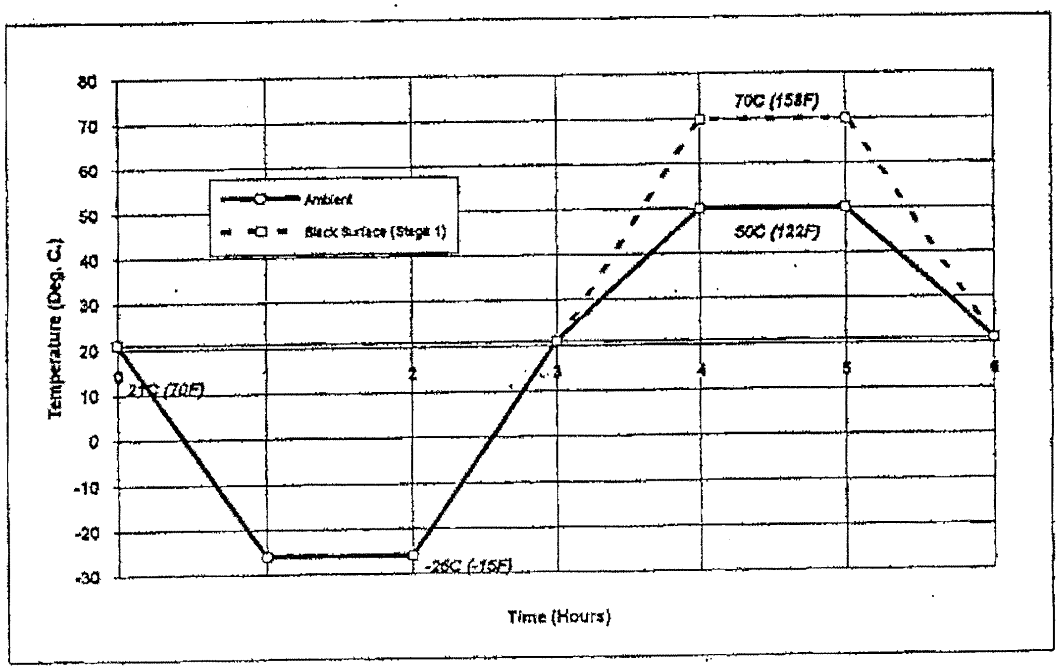
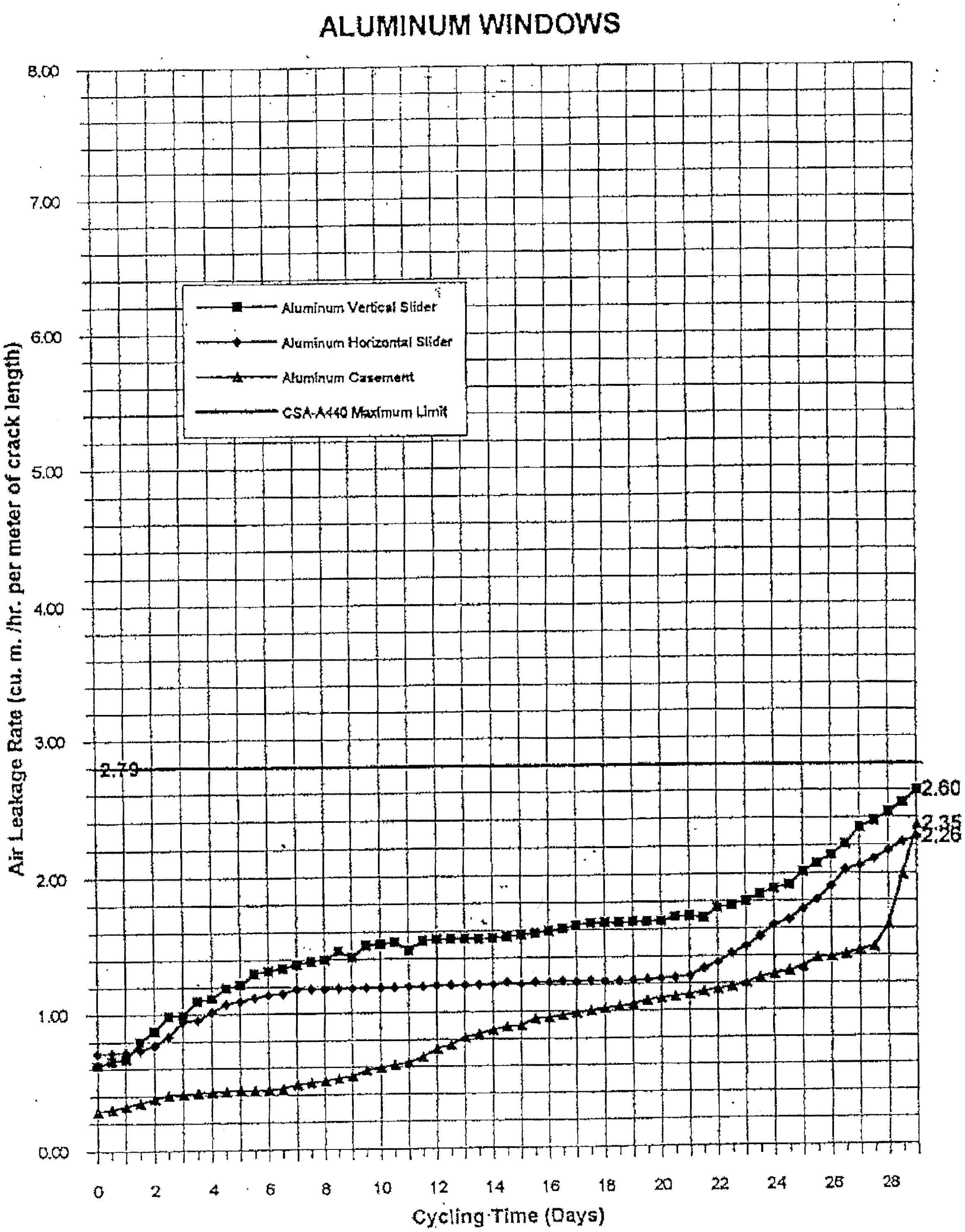


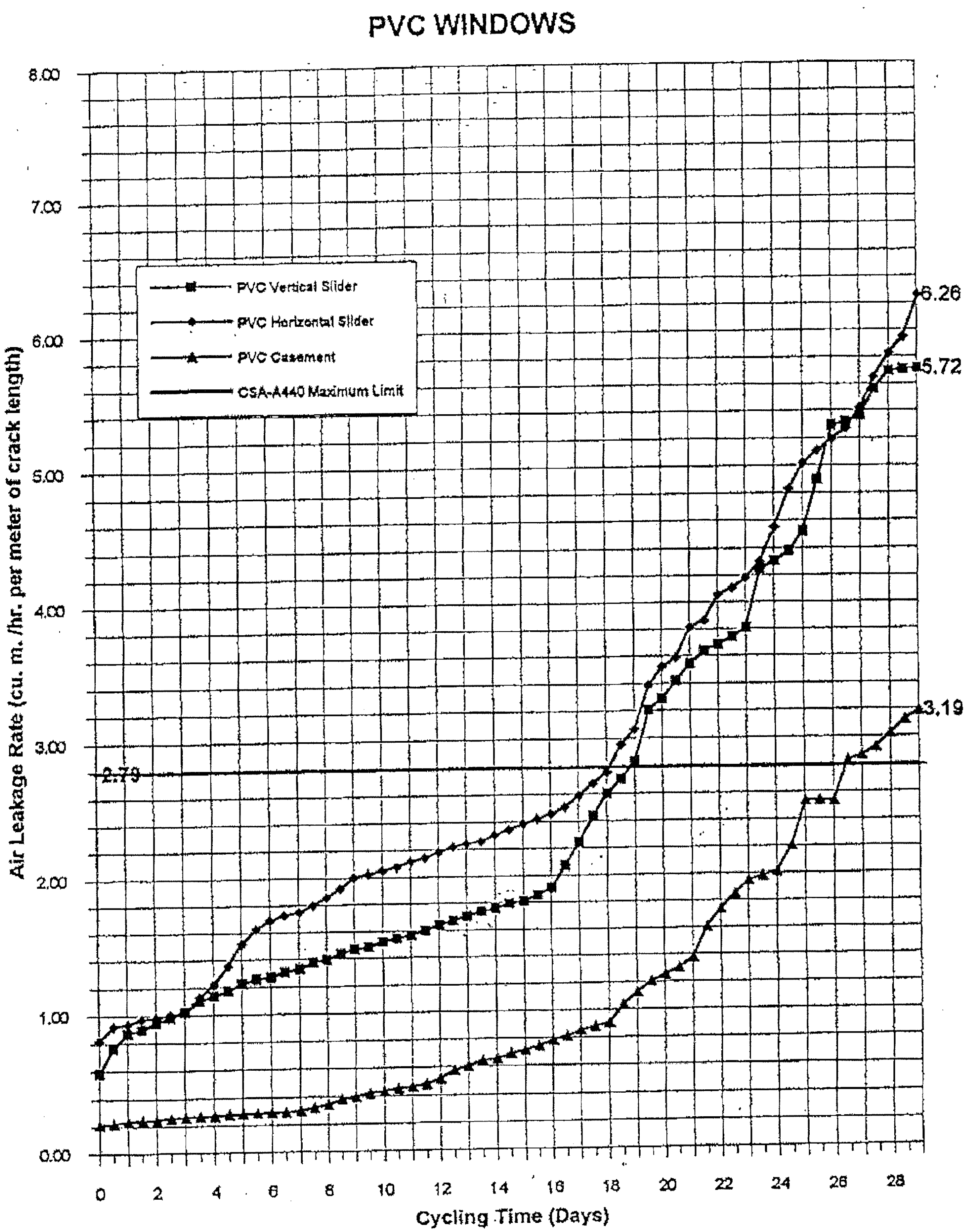
Figure (2): Typical Temperature Cycle



Temperature: 4 cycles (-26 to +70 deg. C.) per day. Pressure: 1 cycle (0 to -1.5 kPa) per minute

Figure (3): Window Air Leakage vs. Temperature/Pressure Cycling

(AEC2.XLW)AEC-AL2.XLC



Temperature: 4 cycles (-26 to +70 deg. C.) per day. Pressure: 1 cycle (0 to -1.5 kPa) per minute

Figure (4): Window Air Leakage vs. Temperature/Pressure Cycling

[AEC2.XLW]AEC-PVC2.XLC

TABLE (2): TEST RESULTS - ALUMINUM VERTICAL SLIDER

TEST & SPECIFICATIONS	PERFORMANCE		OBSERVATIONS
	Initial	Final	
EASE OF OPERATION MAXIMUM FORCES TO INITIATE AND MAINTAIN MOTION: *Initiate:* < 200 N (45.0 lb) *Maintain:* < 100 N (22.5 lb)	PASS Inner Sash: *Initiate:* 80 N *Maintain:* 70 N Outer Sash: *Initiate:* 80 N *Maintain:* 70 N	PASS Inner Sash: *Initiate:* 80 N *Maintain:* 80 N Outer Sash: *Initiate:* 120 N *Maintain:* 95 N	Visible lineal shrinkage of exposed weatherstrips and PVC air sealing components progressively increasing towards the end of cycling.
AIR TIGHTNESS *(ASTM E283)* A1: < 2.79 $m^3/h.m^{-1}$ (0.50 cfm/ft) A2: < 1.65 $m^3/h.m^{-1}$ (0.30 cfm/ft) A3: < 0.55 $m^3/h.m^{-1}$ (0.10 cfm/ft)	A2 0.62 $m^3/h.m^{-1}$	A1 2.60 $m^3/h.m^{-1}$	

TABLE (3): TEST RESULTS - ALUMINUM HORIZONTAL SLIDER

TEST & SPECIFICATIONS	PERFORMANCE		OBSERVATIONS
	Initial	Final	
EASE OF OPERATION MAXIMUM FORCES TO INITIATE AND MAINTAIN MOTION: *Initiate:* < 90 N (20.2 lb) *Maintain:* < 45 N (10.1 lb)	PASS Inner Sash: *Initiate:* 25 N *Maintain:* 20 N Outer Sash: *Initiate:* 30 N *Maintain:* 22 N	PASS Inner Sash: *Initiate:* 30 N *Maintain:* 20 N Outer Sash: *Initiate:* 30 N *Maintain:* 24 N	Visible lineal shrinkage of all weatherstrips progressively increasing towards the end of cycling.
AIR TIGHTNESS *(ASTM E283)* A1: < 2.79 $m^3/h.m^{-1}$ (0.50 cfm/ft) A2: < 1.65 $m^3/h.m^{-1}$ (0.30 cfm/ft) A3: < 0.55 $m^3/h.m^{-1}$ (0.10 cfm/ft)	A2 0.71 $m^3/h.m^{-1}$	A1 2.35 $m^3/h.m^{-1}$	

TABLE (4): TEST RESULTS - ALUMINUM CASEMENT

TEST & SPECIFICATIONS	PERFORMANCE		OBSERVATIONS
	Initial	Final	
EASE OF OPERATION MAXIMUM FORCES TO INITIATE AND MAINTAIN MOTION: *Sash Lock* *Initiate:* < 200 N (45.0 lb) *Maintain:* < 100 N (22.5 lb) *Operator* *Initiate:* < 60 N (13.5 lb) *Maintain:* < 30 N (6.75 lb)	PASS Operator: *Initiate:* 30 N *Maintain:* 20 N Lock: *Initiate:* 45 N *Maintain:* 40 N	PASS Operator: *Initiate:* 45 N *Maintain:* 28 N Lock: *Initiate:* 80 N *Maintain:* 55 N	The slide-in hollow extruded PVC sash thermal break developed a crack along the top and bottom corners of the hinge-side stile on the 27th day of cycling. The crack reached approximately 100 mm in length at the end of cycling (29 days).
AIR TIGHTNESS *(ASTM E283)* A1: < 2.79 $m^3/h.m^{-1}$ (0.50 cfm/ft) A2: < 1.65 $m^3/h.m^{-1}$ (0.30 cfm/ft) A3: < 0.55 $m^3/h.m^{-1}$ (0.10 cfm/ft)	A2 0.71 $m^3/h.m^{-1}$	A1 2.35 $m^3/h.m^{-1}$	Progressive lineal shrinkage of the frame's flexible PVC leaf weatherstrip and snap-in extruded PVC components near the locks and frame corners.

TABLE (5): TEST RESULTS - PVC VERTICAL SLIDER

TEST & SPECIFICATIONS	PERFORMANCE		OBSERVATIONS
	Initial	Final	
EASE OF OPERATION MAXIMUM FORCES TO INITIATE AND MAINTAIN MOTION: *Initiate:* < 200 N (45.0 lb) *Maintain:* < 100 N (22.5 lb)	PASS Inner Sash: *Initiate:* 80 N *Maintain:* 80 N Outer Sash: *Initiate:* 90 N *Maintain:* 85 N	PASS Inner Sash: *Initiate:* 135 N *Maintain:* 95 N Outer Sash: *Initiate:* 145 N *Maintain:* 85 N	The test window maintained a clean visual appearance and proper function following cycling.
AIR TIGHTNESS (*ASTM E283*) A1: < 2.79 $m^3/h.m^{-1}$ (0.50 cfm/ft) A2: < 1.65 $m^3/h.m^{-1}$ (0.30 cfm/ft) A3: < 0.55 $m^3/h.m^{-1}$ (0.10 cfm/ft)	A2 0.58 $m^3/h.m^{-1}$	FAIL 5.72 $m^3/h.m^{-1}$	

TABLE (6): TEST RESULTS - PVC HORIZONTAL SLIDER

TEST & SPECIFICATIONS	PERFORMANCE		OBSERVATIONS
	Initial	Final	
EASE OF OPERATION MAXIMUM FORCES TO INITIATE AND MAINTAIN MOTION: *Initiate:* < 90 N (20.2 lb) *Maintain:* < 45 N (10.1 lb)	PASS Inner Sash: *Initiate:* 30 N *Maintain:* 25 N Outer Sash: *Initiate:* 30 N *Maintain:* 25 N	PASS Inner Sash: *Initiate:* 65 N *Maintain:* 40 N Outer Sash: *Initiate:* 80 N *Maintain:* 45 N	The test window maintained a clean visual appearance and proper function following cycling.
AIR TIGHTNESS (*ASTM E283*) A1: < 2.79 $m^3/h.m^{-1}$ (0.50 cfm/ft) A2: < 1.65 $m^3/h.m^{-1}$ (0.30 cfm/ft) A3: < 0.55 $m^3/h.m^{-1}$ (0.10 cfm/ft)	A2 0.82 $m^3/h.m^{-1}$	FAIL 6.26 $m^3/h.m^{-1}$	

TABLE (7): TEST RESULTS - PVC CASEMENT

TEST & SPECIFICATIONS	PERFORMANCE		OBSERVATIONS
	Initial	Final	
EASE OF OPERATION MAXIMUM FORCES TO INITIATE AND MAINTAIN MOTION: ***Sash Lock*** *Initiate:* < 200 N (45.0 lb) *Maintain:* < 100 N (22.5 lb) ***Operator*** *Initiate:* < 60 N (13.5 lb) *Maintain:* < 30 N (6.75 lb)	PASS Operator: *Initiate:* 20 N *Maintain:* 20 N Lock: *Initiate:* 30 N *Maintain:* 30 N	PASS Operator: *Initiate:* 50 N *Maintain:* 30 N Lock: *Initiate:* 80 N *Maintain:* 80 N	The test window maintained a clean visual appearance and proper function following cycling.
AIR TIGHTNESS (*ASTM E283*) A1: < 2.79 $m^3/h.m^{-1}$ (0.50 cfm/ft) A2: < 1.65 $m^3/h.m^{-1}$ (0.30 cfm/ft) A3: < 0.55 $m^3/h.m^{-1}$ (0.10 cfm/ft)	A3 0.21 $m^3/h.m^{-1}$	FAIL 3.19 $m^3/h.m^{-1}$	

TABLE (A1): DESCRIPTION OF TEST SAMPLE - VERTICAL SLIDER

TYPE	1000 mm wide x 1600 mm high, thermally broken aluminum (frame and sash), vertically sliding, double hung, window consisting of two inward-tilting and sliding sash panels, each supported with one pair of sash balances.
FRAME	
Material:	• Extruded aluminum interior and exterior sections joined by a rolled-in rigid extruded PVC thermal break • Extruded rigid PVC thermal break cover and jamb liners
Assembly:	Matched-joint corners, mechanically fastened with four screws each
SASH	
Material:	Extruded aluminum interior and exterior sections joined by a rolled-in rigid extruded PVC thermal break
Assembly:	Mitred-joint corners, mechanically fastened with three screws each
GLAZING	
Type:	Double-pane insulating glass unit, 21 mm finished overall thickness, consisting of two 3 mm thick sheets of glass separated by an aluminum spacer
Method:	Channel glazed with flexible extruded PVC glazing channel spline
WEATHERSTRIP	
Frame:	• Corners sealed with close-cell foam pad and flexible sealant • One row of pile weatherstrip with a centre fin fitted to the head and sill
Sash:	• Pile weatherstrip with a centre fin fitted to the stiles (2 rows) and rails (1 row) • One row of flexible extruded leaf deflector weatherstrip fitted to the exterior side of the lift rail
HARDWARE	
Locks:	Four extruded aluminum spring-loaded locks/lift handles (two per sash)
Balances:	Two pairs of strap spring sash balances with tilt shoes and pivot bars
Tilt Latches:	Two pairs of surface mounted PVC tilt latches

TABLE (A2): DESCRIPTION OF TEST SAMPLE - HORIZONTAL SLIDER

TYPE	1600 mm wide x 1000 mm high, thermally broken aluminum frame, horizontally sliding, double run, window consisting of two inner and two outer sliding sash panels
FRAME *Material:*	• Extruded aluminum interior and exterior sections joined by a rolled-in rigid extruded PVC thermal break • Extruded rigid PVC sill thermal break cover and snap-in PVC head track liner with open-cell sponge spring strip
Assembly:	Matched-joint corners, mechanically fastened with four screws each
SASH	Extruded aluminum, mitred-joint, corners mechanically fastened with rigid polystyrene corner keys and one screw each.
GLAZING *Type:*	Single-glazed with 3 mm thick sheet of float glass
Method:	Channel glazed with flexible extruded PVC glazing channel spline
WEATHERSTRIP *Frame:*	Corners sealed with close-cell foam pad and flexible sealant
Sash:	• Pile weatherstrip with a centre fin fitted to the rails (2 rows), pull stiles (2 rows) and meeting stiles (1 row) • Corners sealed with flexible sealant
HARDWARE *Locks:*	Four extruded aluminum spring-loaded locks/pull handles (one per sash)
Sash Rollers:	Four pairs of nylon rollers

TABLE (A3): DESCRIPTION OF TEST SAMPLE - CASEMENT

TYPE	700 mm wide x 1600 mm high, thermally broken aluminum (frame and sash), outward-projecting casement window
FRAME	
Material:	Extruded aluminum interior and exterior sections joined by a rolled-in rigid extruded PVC thermal break
Assembly:	Butt-joint corners, mechanically fastened with three screws each
SASH	
Material:	Extruded aluminum interior and exterior sections joined by a slide-in rigid hollow extruded PVC thermal break
Assembly:	Mitred-joint corners, mechanically fastened with four screws each
GLAZING	
Type:	Double-pane insulating glass unit, 20 mm finished overall thickness, consisting of two 3 mm thick sheets of glass separated by an aluminum spacer
Method:	Laid-in glazed with interior extruded aluminum glazing stops and interior glazing spline
WEATHERSTRIP	
Frame:	One row of dual durometer extruded PVC leaf-type weatherstrip
Sash:	One row of woven pile weatherstrip with a centre double fin fitted to the sash thermal break
HARDWARE	
Locks:	Two steel die-cast lever locks mechanically fastened to the jamb with two screws each
Keepers:	Two steel keepers mechanically fastened to the stile with two screws each
Operator:	One single arm roto-operator with steel die-cast crank handle
Hinges:	Two single arm hinges
Snubbers:	None

TABLE (B1): DESCRIPTION OF TEST SAMPLE - VERTICAL SLIDER

TYPE	1000 mm wide x 1600 mm high, double hung window consisting of two inward-tilting and vertically sliding sash panels, each supported with one pair of sash balances.
FRAME	
Material:	Non-reinforced extruded rigid white PVC
Assembly:	Thermally welded mitred corners
SASH	
Material:	Non-reinforced extruded rigid white PVC
Assembly:	Thermally welded mitred corners
GLAZING	
Type:	Double-pane insulating glass unit, 21 mm finished overall thickness, consisting of two 3 mm thick sheets of glass separated by an aluminum spacer
Method:	Laid-in glazed with interior extruded rigid PVC glazing stops
WEATHERSTRIP	
Frame:	One row of pile weatherstrip with a centre fin fitted to the sill
Sash:	Pile weatherstrip with a centre fin fitted to the stiles (3 rows), meeting rails (1 row) and top rail (1 row)
HARDWARE	
Locks:	Two steel die cast cam locks with steel keepers
Balances:	Two pairs of strap spring sash balances with tilt shoes and pivot bars
Tilt Latches:	Two pairs of surface mounted PVC tilt latches

TABLE (B2): DESCRIPTION OF TEST SAMPLE - HORIZONTAL SLIDER

TYPE	1600 mm wide x 1000 mm high window consisting of two inward-tilting and horizontally sliding sash panels
FRAME	
Material:	Non-reinforced extruded rigid white PVC
Assembly:	Thermally welded mitred corners
SASH	
Material:	Non-reinforced extruded rigid white PVC
Assembly:	Thermally welded mitred corners
GLAZING	
Type:	Double-pane insulating glass unit, 21 mm finished overall thickness, consisting of two 3 mm thick sheets of glass separated by an aluminum spacer
Method:	Laid-in glazed with interior extruded rigid PVC glazing stops
WEATHERSTRIP	
Sash:	Pile weatherstrip with a centre fin fitted to the rails (2 rows), meeting stiles (1 row) and pull stiles (2 rows)
HARDWARE	
Locks:	Two steel die cast cam locks with steel keepers
Sash Rollers:	Two pairs of nylon rollers

TABLE (B3): DESCRIPTION OF TEST SAMPLE - CASEMENT

TYPE	700 mm wide x 1600 mm high outward-projecting casement window
FRAME	
Material:	Non-reinforced extruded rigid white PVC
Assembly:	Thermally welded mitred corners
SASH	
Material:	Non-reinforced extruded rigid white PVC
Assembly:	Thermally welded mitred corners
GLAZING	
Type:	Double-pane insulating glass unit, 22 mm finished overall thickness, consisting of two 3 mm thick sheets of glass separated by an aluminum spacer
Method:	Laid-in glazed with interior extruded rigid glazing stops
WEATHERSTRIP	
Frame:	Two rows of extruded flexible PVC bulb-type weatherstrip
Sash:	One row of woven pile weatherstrip
HARDWARE	
Locks:	One lever, three-point sash lock
Keepers:	Two steel keepers
Operator:	One single arm roto-operator with steel die-cast crank handle
Hinges:	Two single arm hinges
Snubbers:	Two external steel snubbers mounted at one-third points

CAN-BEST

SUMMARY OF NFRC/AAMA TESTING CRITERIA

Test Criteria	
Ambient Air Temperature Range	- 20°F to 125°F
Surface Temperature	70°F to 160°F
Pressure Cycling	ASTM E 1233
Air Infiltration Pressure Differential	1.57 psf
Motion Cycles	1000 (AAMA 910)
Pressure Cycles	100 (ASTM E 1233)
Operating Breakaway Force	ASTM E 2086